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PHENOMENOLOGICAL APPROACH TO TRAINING

By

Gary A. Klein

ADVANCED SYSTEMS DIVISION
Wright-Patterson Air Force Base, Ohio 45433

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AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

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Current approaches to training attempt to break complex tasks into simple, discrete steps. This attempt while valuable for teaching procedural tasks, may not be optimal for teaching complex perceptual and motor tasks; it is valuable for initial stages of training, but may not be optimal for training to highly proficient levels of performance. The assumptions behind current approaches to training are questioned. A phenomenological approach is discussed as a means for supplementing the traditional methods, and for accomplishing high proficiency training of complex perceptual-motor tasks. A phenomenological approach would emphasize wholistic features of tasks, and shifts in perspective that develop with competence. Such an approach could provide a theoretical framework for the use of modeling, demonstrations, prediction displays, and other instructional methods.

PREFACE

This report represents a contribution to the research program of project 1710, Training for Advanced Air Force Systems, Dr. Ross L. Morgan, Project Scientist; task 171003, Training Implications of New Military Technology, Mr. Bertram W. Cream, Task Scientist. It is an expanded version of a paper presented at the 38th Military Operations Research Society (MORS) Meetings, Fort Eustis, Virginia, December 1976, entitled "Phenomenological Analysis of Proficient Man/Machine Performance," and selected as the best paper of the working session in which it was presented.

The application of a phenomenological approach to military training requirements is certainly not conventional. However, if training methods are only developed from a limited set of traditional psychological theories, then the opportunity is lost for going beyond the limitations of traditional theories, and for devising means of overcoming these limitations.

Appreciation is expressed to Mr. Bertram Cream, for the insightful criticisms and questions addressed to drafts of this report, which have helped in clarifying and developing many of the arguments, and to Dr. Ross L. Morgan and Dr. Harold Palmer-Alleman, for suggesting means of clarifying sections of the report.

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I. INTRODUCTION

The goal of this report is to determine the training methods that can most effectively develop highly proficient performance. The molecular, analytic techniques currently used in the Air Force will be described, and the limitations of these techniques for developing highly proficient performance will be presented. Finally, a phenomenological approach to training highly proficient performance will be discussed. A phenomenological approach differs from a behavioral one in that it focuses on the way a task is experienced, rather than on the overt responses performed. It will be suggested that a highly skilled performer experiences a task differently than a novice, and that methods which help develop such an experiential shift may be valuable for developing high proficiency performance. The report will not present specific details of a phenomenological approach, but will present reasons for believing that such an approach would be a valuable method for aircrew training. In addition, the report will not claim that a phenomenological approach can *replace* more traditional methods, but will suggest that a phenomenological approach can *supplement* traditional training methods by addressing some training issues that are not effectively handled by traditional methods.

II. MOLECULAR ANALYSIS OF COMPLEX BEHAVIOR

Air Force procedures for developing training programs are described in AFM 50-2 and AFP 50-58 as the instructional systems development (ISD) approach. The Air Force ISD approach is based on the molecular analysis of complex behavior. It attempts to break a complex task down into a set of discrete steps. These steps may be performed either in a fixed sequence, or according to specific, p edefined contingencies. Each discrete step has its own input conditions, required action, and criteria for success. For example, AFP 50-58, Volume 1, describes how the ISD process would be applied to the procedure of starting a jet engine, and recognizing malfunctions requiring the engine to be shut down. Each action (e.g., Turn Fuel Boost Pump Switch ON) is listed with an indication of success (Fuel Boost Warning Light Goes OFF) and a description of what action to take if the previous action has been unsuccessful.

The ISD approach is related to both stimulus-response and information-processing models in psychology. The analysis of complex performance into simpler discrete steps is related to some behaviorists' use of S-R chains to explain performance, and AFM 50-2 specifically states that the work on programmed instruction was one of the major influences on the development of ISD. Certainly the ISD approach reflects the development of methods for using behavioral objectives and criterion-referenced measures in training (Mager, 1972).

The analysis of complex performance into simpler discrete steps is also like digital computer programs or flowcharts, which consist of sequences of discrete instructions. Each step in a digital computer program has its initiating condition and its terminating condition, and consists of a clear and simple action to be performed. Because of the similarity of ISD and digital computer programs, the criticisms of digital computer descriptions of human performance presented by Dreyfus (1972) have been useful in developing the arguments presented in this report.

Throughout the remainder of this report, discussions of ISD-like methods will refer to: performance described in terms of external cues and feedback, involving measurable responses, steps to be performed according to prespecified sequences, and capable of being communicated in the form of written material. The discussions of ISD should therefore be taken as pertaining to future as well as current ISD methods. If future training methods depart from these characteristics, so as to include internal cues, non-fixed-step sequences, etc., then it would be questionable as to whether those methods could be considered ISD methods.[1]

[1] This may appear to be a narrow definition of ISD. Experienced and sophisticated training program developers may include more wholistic procedures in their ISD approaches, and may feel that ISD is basically an attempt to be systematic or reasonable in developing training programs. There is certainly little to argue with in the goals of being systematic or reasonable. However, such goals no longer constitute an approach. The ISD approach was developed for nonexperienced personnel, as a specific set of procedures that would ensure the development of adequate training programs. It is not the intent of this report to set up a "straw man" argument simply by maintaining the formal conception of ISD. To the extent that experienced practitioners are deviating from the procedures defined in AFM 50-2 and AFP 50-58, they may be reflecting precisely those dissatisfactions with molecular training approaches that helped generate this report.

The description of tasks as sequences of discrete steps has two major advantages. First, it allows us to define and measure the accomplishment of training objectives. This is a basic goal of the ISD approach. Second, the molecular ISD task description allows us to develop a training program directed at the teaching of these sequences of discrete steps. Thus, training personnel can define the behavioral criteria for adequate performance, and can also develop a teaching program for meeting those criteria. The ISD approach has been quite valuable for training a variety of tasks.

However, there are some limitations to the use of the ISD method (see also Cream, Eggemeier and Klein, 1975; Klein 1976). It is excellent for training *procedural tasks*. But it is limited with regard to complex motor and perceptual-cognitive tasks. That is, if the task is to follow a set of instructions, or a sequence of steps, such as starting a jet engine, then the method of analyzing this task into a series of discrete steps works well. But when the task becomes more complex, involving interrelated rather than independent actions, problems arise. The ISD method can be used to train a student to operate a radar scope, but there has been no successful demonstration of IS') methods for training the interpretation of radar displays. For nonprocedural complex tasks, it is quite difficult to define specific training objectives. For example, Knoop and Welde (1973) found that experienced pilots could not agree as to how specific actions are combined to yield adequate performance of basic aerial maneuvers. Ther·· is also the danger of distorting complex tasks by attempting to define them as sequences of discrete steps. This is illustrated by the air-to-air gunnery task. A major training requirement is to learn the relationship between the initial attack maneuvers and the eventual set of possible gunnery angles and configurations. The pilot must learn the fighter/target maneuvering dynamics well enough to be able to anticipate when the target is about to be open to attack. Otherwise, this opportunity may be missed, since it is frequently of short duration. These relationships are dynamic features of the entire attack, and are difficult if not impossible to represent by sets of temporally limited discrete steps, each defined as a simple cue/reaction instruction. Putting this another way, try to visualize a 2-dimensional flowchart describing what the student needs to know in order to perform the air-to-air gunnery task. It is hard enough to decide what the decision points and discrete actions would be, let alone capture the important contingencies and interrelationships involved.

Another limitation is in the training of abstract "affective skills" such as attitude, judgement and agressiveness, which may be an important part of combat success (see Mager, 1972). Such emotional behaviors do not readily fit into a cue/reaction framework.

Up to this point, this report has discussed *complex* tasks, but the major emphasis of the report is the development of methods for *high-proficiency training*.

III. MOLECULAR ANALYSIS AND HIGH-PROFICIENCY TRAINING

Molecular task descriptions do not seem to be adequate for the training and evaluation of highly proficient performance on nonprocedural tasks. As Robert Miller (1974) has stated, "Current descriptions and analyses represent the overt facets of the step-by-step performance of a novice. Seldom do they depict the smooth and co-ordinated performance of the highly skilled and efficient performer . . ." (p. 1). Miller also noted that "when current task descriptions (or task analyses) are used to specify the goals or objectives of training programs, the lesser goal of 'novice performance' is accepted rather than systematically seeking the best ıth to the highest degrees of proficiency." (p ,.

We can consider two questions in thinking about high-proficiency training. First, can molecular task descriptions, such as ISD, adequately describe the high-proficiency performance of complex tasks? The previous section argued that the answer to this question is "NO." However, for those who remain unconvinced and retain their beliefs in the adequacy of molecular task descriptions, the second question is: "If it is possible to describe complex nonprocedural tasks in terms of discrete steps, does high-proficiency performance consist of following those steps?" In this section it will be suggested that the answer to this second question is also "NO." It will be further argued that the use of a molecular description may inhibit the development of the molar or wholistic descriptions necessary for training high-proficiency performance.

It is important to recognize that performance can be *described* as a sequence of steps without implying that the performance consists of *following* those steps. Some examples may help illustrate this point.

Instructor pilots (IP) working in ISD teams are frequently charged with developing ISD descriptions of complex performance. They prepare such descriptions, but will typically admit, on an informal basis, that they do not follow those ISD steps when they themselves are flying.

There is an important distinction between *describing* and *explaining* performance. It may be possible to describe the orbit of the moon in terms of a flowchart of discrete steps, but this does not explain *how* the orbit is maintained. The moon does not "know" those steps, has not learned them, is not following them, and does not display any purposive behavior. The point is that we can speak of performance that is lawful without making any claims about following simple steps or instructions. Similarly for human performance, lawful and predictable performance need not be assumed to depend on the following of discrete steps.

Let us assume (for argument's sake) that the task of making a turn on a bicycle may be described by a flowchart of discrete steps. This would not mean that a competent bicylist was following those steps, since bicycle riders are typically unaware of following any steps. It can be argued that the steps have been "internalized" - that is, learned so well that they do not require conscious awareness. But this is unlikely, since the task is much more complex than the tasks that we usually find internalized (such as tying one's shoes). The task cannot be described by a simple strategy, such as "lean into the turn." Somehow, the bicycle rider is consistently able to select the angle of the bicycle to the road as a function of actual speed, expected speed at the completion of the turn, steepness of grade, wind direction and velocity, sharpness of turn desired, and nature of road surface, and to make instantaneous corrections as necessary. A hypothetical set of steps and contingencies describing such performance would be quite difficult, if not impossible to understand, let alone to accomplish instantaneously. It is therefore implausible that a set of steps or contingencies that are incomprehensible to most bicycle riders on the conscious level are at the same time well learned and smoothly executed at the unconscious level. As a final point, no one would attempt to use such a series of steps or contingencies to teach a novice how to ride a bicycle, even if the novice had a Ph.D. in mathematics.

One essential reason for believing that molecular task descriptions cannot be relied on to guide the training of nonproceduralized tasks to high proficiency levels, has to do with context-bound and context-free qualities of descriptions. In our everyday world, we frequently encounter ambiguous sentences or instructions, such as "I enjoy debriefing officers" or "Returning veterans can be dangerous." We can readily understand such sentences, because they are clear within the context of the situation. We live in, understand, and can easily apply situational context, which is built up out of our experience. However, computer programs, flowcharts, and ISD task analysis sheets cannot accept ambiguous instructions. For this reason, care is taken in developing unambiguous, context-free instructions and steps, and in relating these to the important contingencies and background conditions necessary to carry out each instruction. In this way, context is added artificially, and in a very cumbersome way. The cost of extracting context to obtain unambiguous messages, and then adding it later to allow the interpretation of these messages, is considerable. For digital computers, the cost is in memory capacity, and serves as a barrier to the development of complex programs. For ISD materials, the cost is in the additional categories and the cross-referencing needed to convey additional contingencies, all of which reduce the comprehensibility and utility of the materials. The result in both cases is an artificial communication system that is essentially a distortion and diminution of human capability.

The conclustion is that performance of complex nonprocedural tasks does not consist of following sequences of discrete steps. In fact, performance might be impaired by requirements to follow sequences of steps. For example, the concept of a fixed cross-check is strongly emphasized in Undergraduate Pilot Training – a fixed sequence of visual scanning of instruments and dials. But DeMaio, Parkinson, Leshowitz, Crosby, and Thorpe (1976) found that while IPs could find errors in visual displays more quickly than trainees, eye movement data showed that the IPs were using the instructed systematic visual search procedures significantly *less* than the trainees. The IPs also showed significant improvement in a novel scanning task, whereas the trainees, with their rigid scanning patterns, showed no improvement in performance. Clearly, the steps that the trainees are being taught do not support highly proficient performance. Presumably, with experience the students develop more effective visual scanning patterns. But the question remains as to whether the initial training promotes or interferes with the development of effective scanning performance. There is also a question of whether training methods could be formulated to assist students in moving rapidly and effectively from the adequate to the proficient scanning performance.

There is another danger. If complex tasks can be described in terms of sequences of discrete steps, and can be trained as such steps, then any human capabilities beyond a step-by-step level of functioning may be lost. In the area of maintenance training, troubleshooting procedures that consist of sequences of fixed steps can be applied to a number of equipment malfunctions. These procedures can be presented to maintenance personnel. An example is the Fully Proceduralized Job Performance Aids (including troubleshooting aids) developed for AFHRL by Joyce, Chenzoff, Mulligan, and Mallory (1973). These aids are valuable for allowing the novice to quickly perform useful functions. But they may prevent the development of sophisticated performance strategies that allow experienced personnel to shortcut the relatively inefficient and inflexible algorithms mandated by the Job Performance Aids.

Miller's concerns, and the arguments presented in this section, raise the question: "How can we depict the smooth and coordinated performance of the highly skilled and efficient IP?" If step-by-step descriptions are not adequate, what is required?

IV. PHENOMENOLOGICAL DESCRIPTION OF HIGH PROFICIENCY PERFORMANCE

If molecular models of performance are of questionable adequacy for describing and training high proficiency, then alternate approaches are needed. The present section of this report will examine a phenomenological approach, loosely modelled after the work of Dreyfus (1972).

Since this report has questioned the value of molecular descriptions, an obvious alternative is a wholistic description. This will be characterized as a phenomenological approach, since the primary concern will be to describe how a task is differentially *experienced* by novices and experts, rather than to explore *behavioral* differentiations. Thus, a sequence of musical notes is perceived differently by a novice trying to remember the order and duration of each, and by the competent musician who is trying to work out the most effective phrasing. Similarly in aircrew training, the performance of a sequence of control tasks will be experienced differently by the novice trying to remember all the actions plus the extent and duration of each, and the experienced pilot who is concerned with the overall maneuver. It is assumed that by having the trainee learn to experience a task in a similar way to the expert, the trainee's performance will take on some of the performance characteristics of the expert; e.g., smooth and integrated performance. This assumption is basic to a phenomenological approach to aircrew training, and will, of course, require empirical support. The purpose of this report is to describe this assumption and its implications, since they may be valuable for the development of future aircrew training methods.

Two aspects of a phenomenological approach seem especially important for aircrew training: the wholistic understanding of the task, and the shifts in perspective from novice to expert performance. These two areas are distinct but obviously interrelated. They will be discussed in order.

1. *Wholistic Understanding.* It is suggested that the IP understands the task wholistically. For example, the relationship between early maneuvers and eventual attack position is an important part of an aerial gunnery task. The implications of early maneuvers on the eventual profiles are felt by the skilled pilot from the very beginning of the engagement. The performance of the IP is smooth because it is reflecting current and anticipated task demands simultaneously. The performance of the novice is jerky because he is performing each action in isolation. He doesn't see how one action affects any others that have to be performed concurrently. Nor does he see how an action will affect other actions performed later in time. Therefore, the novice is continually making abrupt transitions from one independent action to another, rather than smooth transitions between interrelated parts of an overall task. A phenomenological approach may be much more likely to preserve the awareness of overall task character than would a fragmented, molecular description in terms of momentary sequences of simple, basic task elements. This is because a phenomenological approach would not segment the task to begin with, and therefore would not have to figure out a way to recombine the segments.

The importance of wholistic understanding of a task is illustrated by comments by a maintenance technician responsible for fault isolation and inspection of electronics instrumentation: "The expert differs from the trainee in that he knows the whole system. He understands how each of the components interacts. Even when you move him to a new piece of equipment, he is more sensitive to this interaction than a trainee would be. The trainee may know that component interaction is important, but he doesn't have a real appreciation for how this interaction comes into play. In troubleshooting, the expert may try to isolate a fault by tracing signals through various components, and eliminating the good components. The trainee, who is limited in his understanding of component interaction, can't tell when a component can be eliminated from consideration, and so the trainee isn't able to use some powerful methods for troubleshooting."

One radar expert (who is also a member of an ISD team), when asked to describe the difference between novice and competent performance, said, "It's like speaking a foreign language. When the beginner comes up against an excited foreigner, he is forced to frantically flip through his dictionary, and usually can't keep up. The fluent speaker is hearing ideas and arguments, not words. The radar student concentrates on the little things, the individual symbols, and has trouble making sense out of the whole display. When the scope is misaligned, the trainee has trouble adjusting. The expert understands the total scope display. He isn't affected by scope misalignment, just as a fluent speaker of a language can understand someone with an accent."

Wholistic methods may also support the development of affective skills such as attitude and aggressiveness, which are considered by some to be integral to mission performance. Such emotional components may drop out when a task is segmented, since they are really an outgrowth of the wholistic performance of the task, and of representing initiating and goal conditions simultaneously with performing the control operations.

Brown, Waag, and Eddowes (1975) evaluated a training method for teaching pilots to fly a ground controlled approach (GCA) and noted that the development of competence in the GCA task seemed to be based on the trainee's getting an "insight" (their term) into the GCA task. This "insight" refers to a grasp of the overall task. Brown et al. were evaluating a training method designed to keep error rates constant, and introduce new aspects of the task systematically. They did not find that there was any value to keeping error rate constant, and suggested that a varied set of experiences might be more helpful in the development of insight than a systematic set of experiences which introduced new demands one at a time. Thus, Brown et al. are suggesting the importance of a wholistic understanding of the task, and are making recommendations about training methods to instill this wholistic understanding.

Another means of providing wholistic understanding is through modelling, which can be provided directly by an instructor, or through the use of taped demonstrations. The value of modelling is to show the interrelationships and coordinations involved in a task. Demonstration capabilities are not new to the Air Force. What is being suggested is the potential value of a phenomenological approach for providing a theoretical basis for the use of demonstrations and modelling techniques. Such a theoretical basis could allow more efficient use of demonstrations and modelling techniques.

Another method for developing a wholistic understanding of a task is the use of predictor displays (visual plots of the future path of an aircraft, given the current conditions and control settings). These have additional advantages and disadvantages, but their primary value is best understood from a phenomenological viewpoint: they represent the consequences and implications of actions, as the actions are performed, and thus allow the trainee to integrate the beginning and end of a task.

Wholistic instruction can also be provided through imagery techniques requiring subjects to generate visual images of objects and events that are not present (Kulhavy & Swenson, 1976; Paivio, 1971; Richardson, 1969). These techniques have been used with tasks ranging from complex motor performance to simple procedures training. Imagery provides an opportunity to consider several types of actions and events simultaneously, and to display the interrelationships among them. Verbal or written instructions, in contrast, only deal with one action or event at a time. The success of imagery techniques has not been established in the area of aircrew training, but hopefully these techniques will be subjected to experimental evaluation.

2. *Shifts in Perspective*. To illustrate what is meant by a shift in perspective, one former IP described the shift from novice to competent pilot in this way: "You start off after finishing UPT being able to fly, but you are always concerned with remembering everything they told you, and not missing any major step. Flying at this time is

quite stressful, and not enjoyable. Eventually, you get to a point where you are no longer flying the airplane, but are feeling yourself fly. And that's when it becomes easy and worthwhile. Before, you were strapping yourself into an airplane, which you flew. Now, you strap the airplane onto you, and you fly." What is being described is a shift in experience from operating a forbidding piece of machinery, to automatically making control adjustments while completing a larger airborne mission. A similar shift occurs in learning to use a radar scope. Experts describe how they start by reading symbols off the scope face, trying to remember what the symbols mean, and how to tune them in better. But eventually, they experience the radar targets *through* the radar scope, which they adjust as one blinks an eye to see better or cups an ear to hear better. The shift is from operating a piece of equipment to operating with the piece of equipment. The novice experiences a separation between himself and the equipment he is operating. The expert has eliminated this separation, and is functioning with the equipment as with a body part.

The use of imagery techniques would seem to be called for in the following comments, collected during an interview with a pilot trained in air-to-air combat and working with an ISD unit: "I know what I'm looking for in the end, how I expect to be bearing in on the target, and I also know how each type of maneuver will affect this outcome. I've learned this with experience. The trainee is often trying to solve the attack equations on just one dimension at a time, whereas I can blend all the factors. I tell trainees to try to take a god-like view: not to think of themselves maneuvering against another airplane, but to see themselves from outside their own cockpit, from outside their own aircraft, observing their airplane relative to the enemy airplane. This ability to represent your aircraft from other than your own cockpit helps tremendously, and is developed with experience. In my own mind, I am seeing myself from another point, usually from above, and this point moves during the mission. Guys who fly canned maneuvers, making specific responses to specific situations, usually are OK for one or two runs, but then they run out of options. There are too many combinations, and they can't handle all the possibilities."

Another type of shift in perspective that is important for aircrew training involves the ability to assume the perspective of others – both crew members and opponents. Cream (1974) has analyzed crew coordination performance and determined that each crew member must have an accurate expectation of the appropriate system operation for each of the other crew members. It is not sufficient to know what messages must be sent and delivered, and when. Effective crew coordination requires a crew member to understand the nature of the task being performed by another. In this way, a radar navigator can understand how any of a variety of unexpected events would impact on the performance of an electronic warfare officer (EWO), and can make the necessary adjustment in his own performance. This relates to the context-bound/context-free discussion presented earlier. If the navigator understands the nature of the EWO's task, then he can anticipate how events, even those never previously encountered, may affect the EWO's performance. The navigator's understanding of the EWO's task, and of his own reactions to any encountered event, provides the context needed for effective interpretation of the EWO's needs and performance. The alternative to training such a perspective shift is to try to train the navigator to be prepared for all possible reactions from the EWO, for all possible contingencies. This is an attempt to substitute contingency rules for contextual information (as discussed earlier). It is impossible to completely specify contingencies and it is inefficient to train using sets of contingency rules. It also restricts the ability of crew members to compensate for each other when necessary.

Shifts in role perspectives are also relevant for interceptor/target interactions. Anecdotal reports from pilots who have had opportunities to fly Communist airplanes; such as the MIG-21, indicate the value of such experiences for aerial combat maneuvering. By learning the handling characteristics of the MIG-21, the MIG-21 no longer represented a neutral target with ill-defined capabilities. It was, instead, a target with understood capabilities, whose capability would be anticipated and countered more easily.

One possible approach to training perspective shifts, primarily those involving man/machine rather than man/man interactions, is through the use of motor analogies. This will be explored in the following section.

3. *Motor Analogies*. In the skilled performance of tasks involving man/machine interaction, the shift in framework seems to involve the elimination of a separation between the man and the machine, so that the operation of the machine is accomplished as naturally as the movement of an arm or a hand. This is sometimes referred to as the development of a "feel for the task." One possible

way of training such phenomenological shifts or "feelings" would be to transfer them from other tasks. Thus, Spence (1973) has described how to teach someone to pull a trigger: the trainee is told that it is like squeezing a lemon. The instructor does not specify how many millimeters to draw the trigger back, but instead finds a motor analogy, which includes the right type of feel.

Tennis instruction provides many such examples. The novice is frequently instructed on how to play up at the net in terms of how high to position the racket face, what angle to stroke with, how to avoid chopping at the ball, how to position and move each foot. The result is typically to leave the novice in a state of instruction-induced paralysis. But if the novice is simply told, "It's like pushing a pie in someone's face," then the result is a smooth coordination of arms, body, feet and racket. The analogy can describe the overall task, rather than focusing on isolated parts of the task.

The use of motor analogies is a potentially important area (see Hesse (1966) and Klein and Weitzenfeld (1976) for additional discussion of the use of analogies). Analogies are a source of hypotheses, not conclusions. An analogy that appeals to an instructor or an instructional program developer may not be applicable to students, and would therefore have to be tested and evaluated.

The use of analogies in training programs would probably require that instructional program development personnel be trained to select, apply and evaluate the analogies. While the use of motor analogies has not been proposed before, there has been some recent work on the use of analogies for instructional purposes. Stelzer (1975) has developed a formal model for selecting analogies for instructional purposes. It is not clear how easily Stelzer's model could be applied to the use of motor analogies for aircrew training. However, the development of a program for teaching the effective selection and use of motor analogies should not be a prohibitive task.

There are means of pre-evaluating analogies. For the task of squeezing a trigger, the analogy of squeezing a lemon could be selected over squeezing a basketball or tweezers, since there are more points of similarity concerning the positioning and movement of the fingers. Analogies can be selected on the basis of similarity, or on the basis of the preservation of causal relationships.

To further illustrate the use of motor analogies for skills training, it has been suggested that serving a tennis ball is like throwing a baseball, whereas the backhand stroke in tennis is like throwing a frisbee. These examples provide different analogies for directing coordinated performance for different aspects of the game of tennis. Let us assume that the trainees consist of women who have never thrown baseballs. The analogy is useless. But it may also suggest that the instructor begin the lesson on the serve by having the women practice throwing tennis balls into the service boxes. This shows how analogies can suggest procedures and hypotheses. In the area of aircrew training, part-task trainers have frequently been used to provide practice on procedures, but they represent a valuable opportunity to provide motor analogies that can be readily applied in the operational environment.

The motor analogies, discussed in the previous paragraphs, consist of well-integrated behaviors, which can be applied as packages, with relatively straightforward translations of individual components. Thus, a tennis player does not play the net exactly as if he or she was holding a pie plate. What remains constant is the coordination of movements, and the relationships involved. That is why the term "motor analogy" was used, rather than referring to the "transfer of well learned responses." An analogy allows the transfer of relationships even when the individual components are different.

V. CONCLUSION

This report attempted to show that current methods for analyzing training and performance are limited. They are based on assumptions that complex behavior can be analyzed in terms of simple discrete steps. These assumptions are questionable for analyzing nonprocedural tasks. The methods are also restricted to the modest goal of developing minimally adequate performance, rather than attempting to develop high proficiency performance.

A phenomenological approach was discussed as a means of describing high-proficiency nonprocedural performance. Two major differences between novice and competent performers were examined: wholistic understanding of the task, and shifts in perspective. A number of potential training methods were discussed for reducing the differences between novice and competent performance: motor analogies, instructional syllabus procedures such as using varied rather than systematic task presentations, modelling and demonstrations, predictor displays, imagery techniques, opportunities for varied role experiences (e.g., learning alternate crew tasks, flying in simulators configured in accordance with enemy aircraft).

It is important to recognize that this report has not presented a specific phenomenological approach, nor has it presented any validated training methods. The attempt has been to discuss the potential value and need for such an approach, and to show that a phenomenological approach can have positive implications for aircrew training.

It is not being suggested that a phenomenological approach is sufficient by itself. Obviously, in a variety of fields initial instruction is in terms of molecular descriptions and discrete steps. Even with tennis, the players must first learn the rules and behavioral objectives for winning and losing points. A phenomenological approach to training is being suggested as a means for subsequently obtaining highly proficient performance. It is being suggested to complement the traditional ISD types of training methods.

It is shortsighted to assume that any specific theory or theoretical framework can serve as an adequate description of human functioning. A photograph of a person, a recording of that person's voice, a chemical analysis of the person's blood, all describe aspects of that person, but none alone is sufficient to completely describe him. An analogy, such as describing atoms as billiard balls, may provide a useful representation. But it would be mistaken to conclude that atoms are nothing but miniature billiard balls. Similarly, the various psychological frameworks, such as stimulus/response, information-processing, and phenomenological, each provide partial descriptions of human functioning. Humans observe cues and emit responses, and a stimulus/response framework may be quite valuable for training procedural tasks, but it is a mistake to conclude that humans are nothing but stimulus/response systems. Humans process information, and information processing paradigms can be quite useful for evaluating the demands of various cockpit layouts on limited attentional capacity. But it would also be a mistake to conclude that humans are nothing but information processing systems. Such a claim confuses the analogy with the phenomenon. Similarly, humans are able to apply their experiences to understanding the performance of others, and phenomenological approaches may be helpful in training crew coordination, but humans also emit responses and process information.

The position is an eclectic one, but it is different from the common form of eclecticism: "I don't know which theory is best, so I just use a little bit of everything." Instead, the present argument is that it is shortsighted to assume that any theoretical framework can be sufficient. It is more effective to understand a variety of frameworks, and to be able to apply the one most appropriate for any given task.

Neither a phenomenological nor an ISD approach can independently produce optimal training. Each has its strengths and limitations. Thus, one important limitation of a phenomenological approach is that it does not provide performance criteria for complex tasks, but instead must rely on subjective judgements and ratings. However, it was also pointed out previously that ISD methods themselves do not provide satisfactory objective performance criteria for non-procedural tasks. It would be a mistake to eliminate subjective ratings if they are replaced with unreliable or irrelevant behavioral objectives. Hopefully, a synthesis of behavioral, information processing and phenomenological methods may overcome the weaknessess inherent in each type of approach used independently.

REFERENCES

AF Manual 50-2. *Instructional system development*. Washington: Department of the Air Force, December 1970.

AF Pamphlet 50-58. *Handbook for designers of instructional systems*. Washington: Department of the Air Force, January 1974.

Brown, J.E., Waag, W.L., & Eddowes, E.E. USAF evaluation of an automated adaptive flight training system. *Proceedings of the 8th NTEC/Industry Conference*, Orlando, FL, 1975.

Cream, B.W. A functional integrated systems trainer for individual and crew coordination training. *Proceedings of the Fourth Annual Symposium on Psychology in the Air Force*, Colorado Springs, CO, 1974.

Cream, B.W., Eggemeier, F.T., & Klein, G.A. Behavioral data in the design of aircrew training devices. *Proceedings of the 19th Annual Meeting of the Human Factors Society*, Dallas, TX, 1975.

DeMaio, J., Parkinson, S., Leshowitz, B., Crosby, J., & Thorpe, J.A. *Visual scanning: comparisons between student and instructor pilots.* AFHRL-TR-76-10, AD-A023 634. Williams AFB, AZ: Flying Training Division, Air Force Human Resources Laboratory, June 1976.

Dreyfus, H.L. *What computers can't do*. New York: Harper & Row, 1972.

Hesse, M. *Models and analogies in science*. Notre Dame: University of Notre Dame Press, 1966.

Joyce, R.P., Chenzoff, A.P., Mulligan, J.F., & Mallory, W.J. *Fully proceduralized job performance aids: handbook for JPA developers.* AFHRL-TR-73-43(II), AD-775 705. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, December 1973.

Klein, G.A. Problems and opportunities in deriving training requirements for the design and utilization of simulators. *Proceedings of the First International Learning Technology Congress and Exposition*, July 1976.

Klein, G.A., & Weitzenfeld, J. *General description of human problem solving*. AFHRL-TR-76-44, AD-A028 476. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, June 1976.

Knoop, P.A., & Welde, W.L *Automated pilot performance assessment in the T-37: a feasibility study*. AFHRL-TR-72-6, AD-766 446. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, April 1973.

Kulhavy, R.W., & Swenson, I. Imagery instructions and the comprehension of text. *British Journal of Educational Psychology*, 1975, **45**, 47-51.

Mager, R.F. *Goal Analysis*. Belmont, CA: Fearson Publishers, 1972.

Miller, R.B. *A method for determining task strategies.* AFHRL-TR-74-26, AD-783 847. Wright-Patterson AFB, OH: Advanced Systems Division, Air Force Human Resources Laboratory, May 1974.

Paivio, A. *Imagery and verbal processes*. New York: Holt, Rinehart & Winston, 1971.

Richardson, A. *Mental imagery*. New York: Springer, 1969.

Spence, D.P. Analog and digital descriptions of behavior. *American Psychologist*, 1973, **28**, 479-488.

Stelzer, J. *Structuring and classifying the content of instructional subject matter.* Unpublished manuscript, June 1975. (Available from the U.S. Army Research Institute, 5001 Eisenhower Avenue, Alexandria, VA 22333.)

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